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The screening of sound in a subsonic flow by a cylindrical airbubble layer and a semi-infinite tube

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CHAPTER I

INTRODUCTION

The problem here under discussion lies in the field of sound waves in layered media. The presence of a layer with a velocity of sound less than that of the surroundings will enable sound waves to travel along great distances. In this domain many investigations have been made e. g. in connection with the propagation of sound in the ocean. Sound velocity in sea-water is a function of depth and reaches a minimum at approximately 1 kilometer under the surface of the sea. It is this minimum that sees to it that waves starting on this level can stay approximately at this level. In this way sound waves can travel over great distances on a depth which is almost exclusively limited to the direct neighbourhood of this minimum and that is why one is speaking of a sound channel [5]. For the analogous rotational problem Sparenberg has examined the existence of such waves [15].

The presence of a layer with a smaller velocity of sound than the surroundings may also have a screening effect for a sound source. A civil application of this phenomenon is the protection of bridge pillars against damage caused e. g. by the blowing up of submerged objects in their vicinity. Here a bubble screen will be placed between the place of the explosion and the object to be protected. This screen that actually consists of a mixture of water and air has indeed a velocity of sound which is much smaller than that of water. This may cause a screening effect both by absorption and by reflection.

The direct motive of the problem treated here was the possibility to screen the noise caused by a ship's propeller

by an airbubble layer. For this purpose air will be squeezed from the nozzle in which the screw is rotating or from the screw itself, so that the screw lies inside a cylinder of a mixture consisting of air and water [17]. The screening effect of this cylinder has to hamper the locating of a ship by gauging the sound waves which are caused by the screw. In order to treat this problem mathematically we have first examined the case of a sound source which is placed on an axis of a two-sided infinite tube which has another density and velocity of sound than the surroundings [6]. Apart from the disturbances caused by the source it was supposed that the media were in rest with respect to the source. For the practical background of the problem this means that the velocity of sound of both media is large with respect to the velocity of the ship.

The addition of a small quantity of air in water causes a great decrease of the velocity of sound in this mixture. The propagation velocity of sound in water is about 1430 m/sec, but in a mixture of 10% air and 90% water it has decreased to about 30m/sec. With regard to this velocity of sound the velocity of a sailing ship cannot be neglected without a closer examination. So in this work we assumed that the media with regard to the source will have a velocity in the direction of the axis of the cylinder. This velocity is assumed to be subsonic for both media.

The presence of a nozzle in which the screw is rotating may be of influence on the screening of the noise caused by the screw. If there is a nozzle we must pay attention to the flow on the edge of this nozzle. To get some knowledge about these phenomena without having too great mathematical complications we considered a nozzle which is half infinite and which stretches upstream to infinity.

The preceding considerations have led to the examination of the following problem. There is a two-sided infinite cylindrically shaped screen of finite thickness and with a circular cross-section in a medium which extends to infinity in all directions. This cylinder consists of a fluid which has a lower velocity of sound and density than the rest of the space. A semi-infinite rigid tube with a negligible thickness is at the inside of the screen. A point source has been placed somewhere on the axis of the cylinder. The media have a uniform subsonic velocity U in the direction of the axis, so that the edge of the tube is a trailing edge.

We shall examine the pressure disturbances caused

by the source. Particularly the field at a great distance from the trailing edge of the tube is examined.

We pay attention to the waves with constant amplitude, which run along the bubble screen both in positive and in negative direction and which are a result of the minimum of the velocity of sound as mentioned in the beginning of this introduction.

From the general problem we deduce several particular cases. In chapter XIX we suppose the source is placed far inside the rigid tube and in chapter XX the source is situated far outside the tube. In chapter XXI we examine the case without a bubble screen.

The problem without a semi-infinite tube is treated in [6] for the special case that the undisturbed media are at rest, hence $U=0$. Chapter XXII gives for this case the most important formulae when the media have a subsonic velocity U .